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Sieracki et al.

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(54) **SYSTEM AND METHOD FOR MONITORING BIREFRINGENT PARTICLES IN A FLUID**

(75) Inventors: **Christian K. Sieracki**, Edgecomb, ME (US); **William H. Nelson**, North Yarmouth, ME (US); **Robert M. Grimm**, Raymond, ME (US); **Scott Ellis**, Topsham, ME (US)

(73) Assignee: **Fluid Imaging Technologies, Inc.**, Scarborough, ME (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 590 days.

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Related U.S. Application Data

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(60) Provisional application No. 61/086,010, filed on Aug. 4, 2008.

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H04N 9/47 (2006.01)
H04N 7/18 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***G02B 21/365*** (2013.01); ***G01N 21/05*** (2013.01); ***G01N 21/23*** (2013.01); *G01N 2201/0627* (2013.01); *G01N 2201/06153* (2013.01)

(58) **Field of Classification Search**
CPC G02B 21/465
USPC 348/79
See application file for complete search history.

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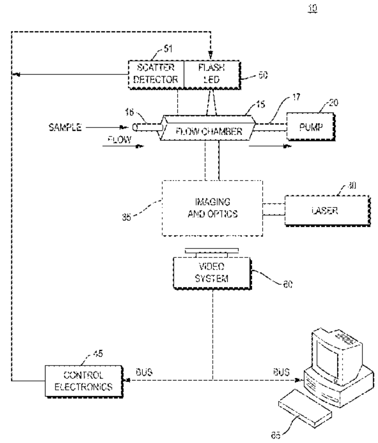
Primary Examiner — Chikaodili E Anyikire
(74) *Attorney, Agent, or Firm* — Caseiro Burke LLC; Chris A. Caseiro

(57) **ABSTRACT**

An imaging system with an imaging mechanism which includes polarization analyzers, which may be crossed polarization analyzers, positioned to provide birefringence images of particles in the fluid passing through the flow chamber. Captured images are of high resolution and may be used in comparison to known images of a library of images. The system and related method enhance the accuracy and sensitivity of particle monitoring by utilizing birefringence imaging combined with particle analysis and the detection of each particle's characteristic features, such as crystalline features. The system includes a scatter detector used to trigger backlighting of the flow chamber and capture images of particles therein.

12 Claims, 8 Drawing Sheets



(51) **Int. Cl.**

G02B 21/36	(2006.01)
G01N 21/05	(2006.01)
G01N 21/23	(2006.01)

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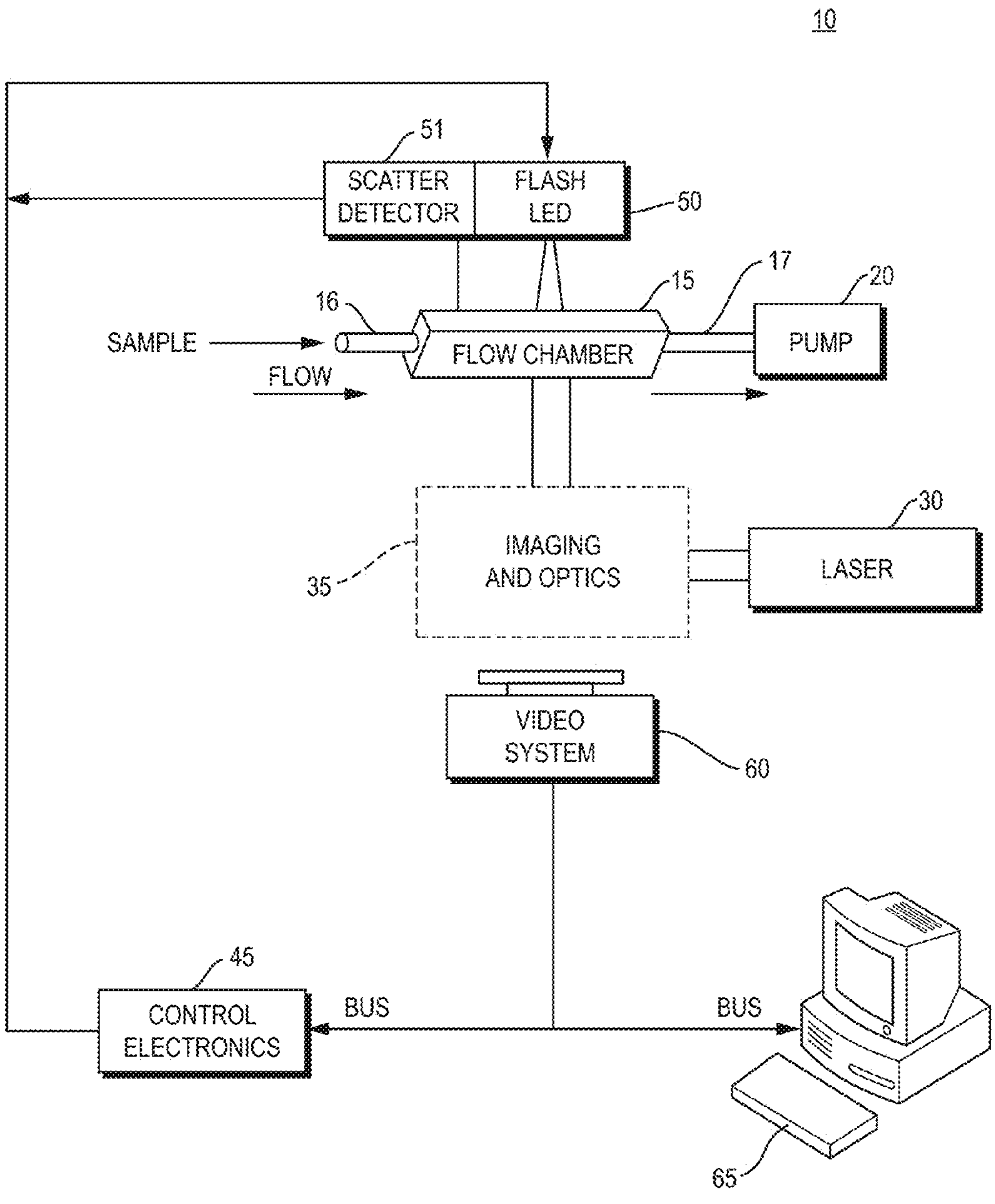
10
51
SCATTER DETECTOR
FLASH LED
50
17
20
16
15
SAMPLE
FLOW CHAMBER
PUMP
FLOW
30
IMAGING AND OPTICS
LASER
35
VIDEO SYSTEM
60
45
CONTROL ELECTRONICS
BUS
BUS
65

FIG. 1

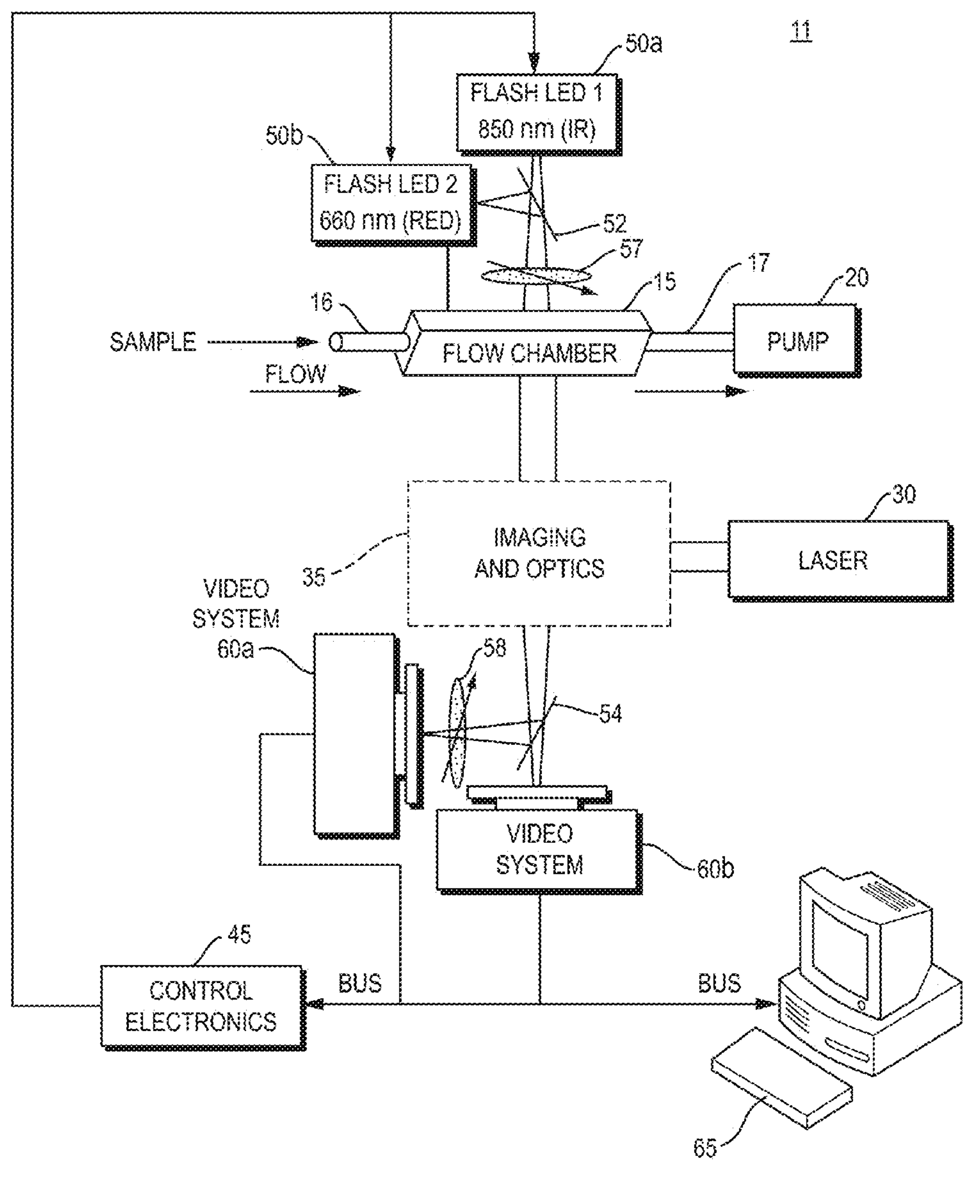
11
50a
FLASH LED 1
850 nm (IR)
50b
FLASH LED 2
660 nm (RED)
52
57
17
20
15
16
SAMPLE
FLOW CHAMBER
PUMP
FLOW
30
IMAGING
AND OPTICS
LASER
35
VIDEO
SYSTEM
60a
58
54
VIDEO
SYSTEM
60b
45
CONTROL
ELECTRONICS
BUS
BUS
65

FIG. 2

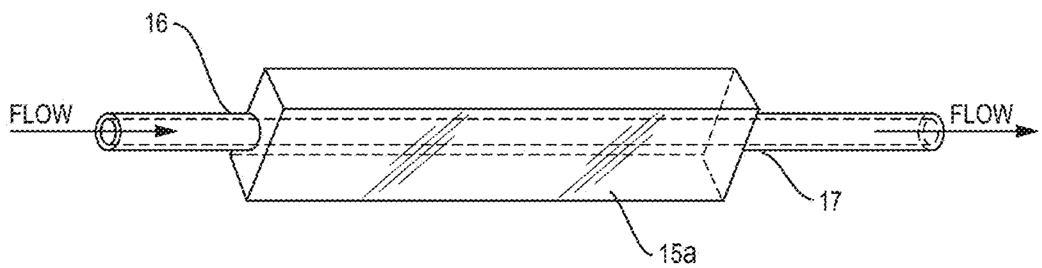

FIG. 3

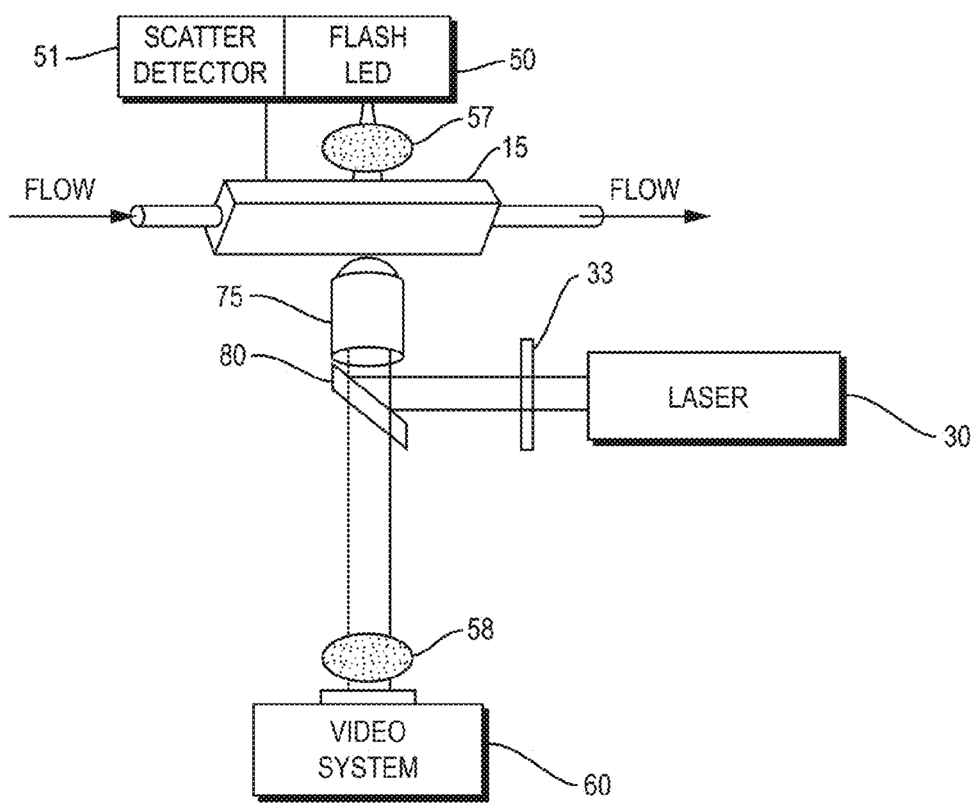
51
SCATTER DETECTOR
FLASH LED
50
57
15
FLOW
FLOW
33
75
80
LASER
30
58
VIDEO SYSTEM
60

FIG. 4

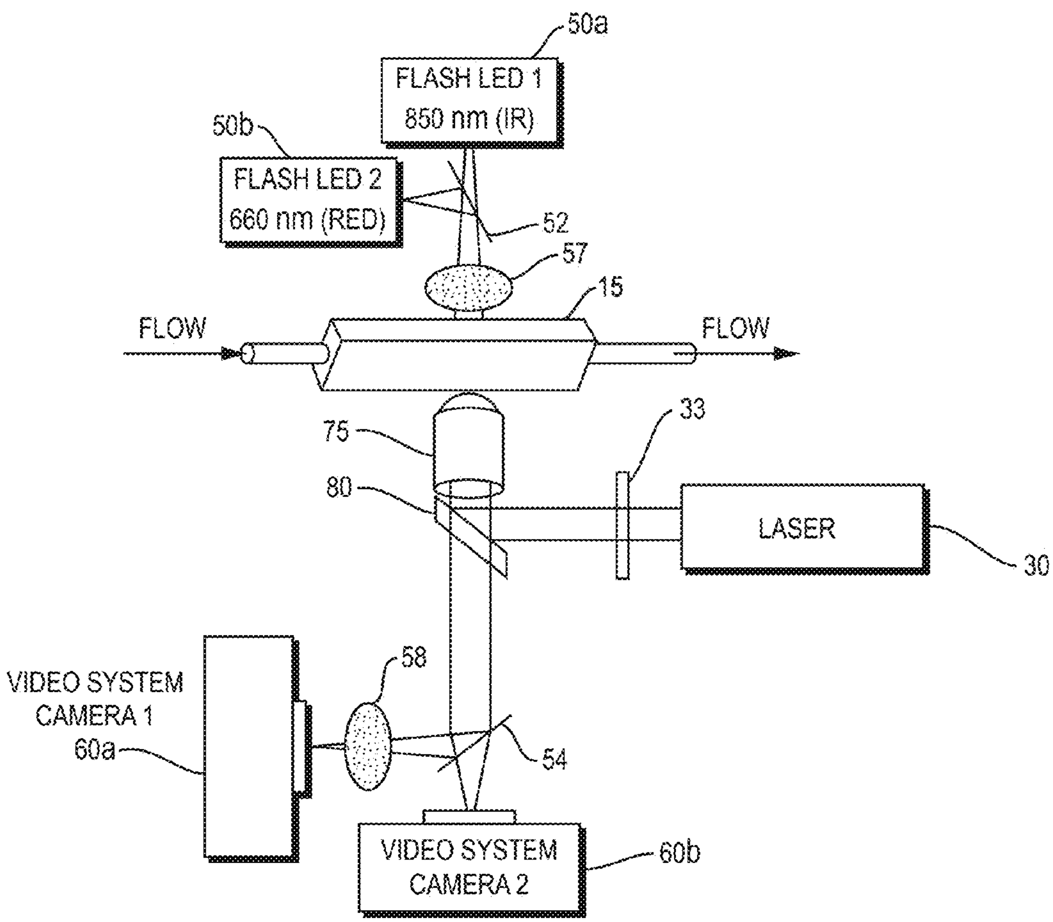
50a
FLASH LED 1
850 nm (IR)
50b
FLASH LED 2
660 nm (RED)
52
57
15
FLOW
FLOW
75
33
80
LASER
30
58
VIDEO SYSTEM
CAMERA 1
60a
54
VIDEO SYSTEM
CAMERA 2
60b

FIG. 5

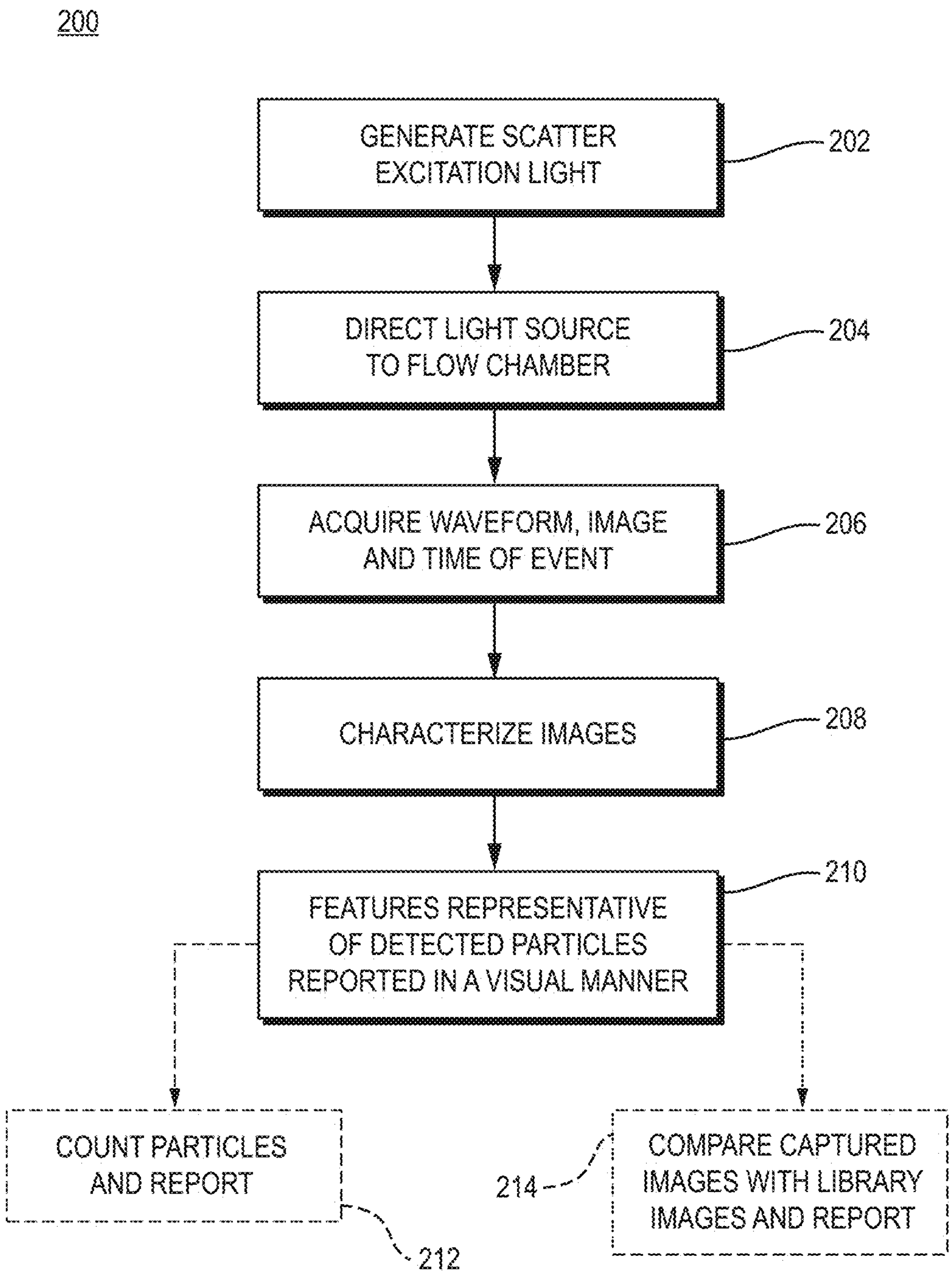
200
GENERATE SCATTER EXCITATION LIGHT
202
DIRECT LIGHT SOURCE TO FLOW CHAMBER
204
ACQUIRE WAVEFORM, IMAGE AND TIME OF EVENT
206
CHARACTERIZE IMAGES
208
FEATURES REPRESENTATIVE OF DETECTED PARTICLES REPORTED IN A VISUAL MANNER
210
COUNT PARTICLES AND REPORT
212
COMPARE CAPTURED IMAGES WITH LIBRARY IMAGES AND REPORT
214

FIG. 6

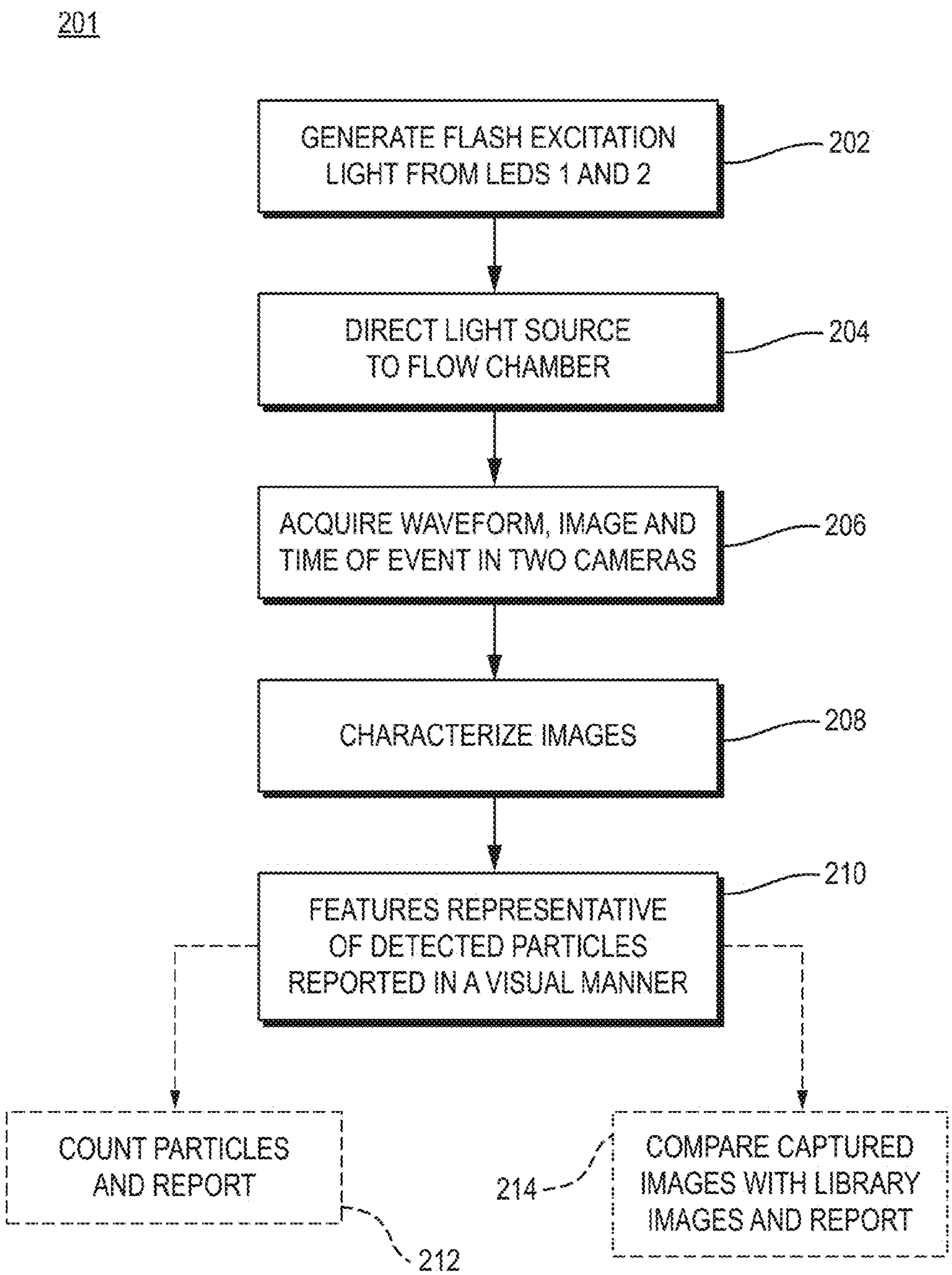
201
GENERATE FLASH EXCITATION LIGHT FROM LEDS 1 AND 2
202
DIRECT LIGHT SOURCE TO FLOW CHAMBER
204
ACQUIRE WAVEFORM, IMAGE AND TIME OF EVENT IN TWO CAMERAS
206
CHARACTERIZE IMAGES
208
FEATURES REPRESENTATIVE OF DETECTED PARTICLES REPORTED IN A VISUAL MANNER
210
COUNT PARTICLES AND REPORT
212
COMPARE CAPTURED IMAGES WITH LIBRARY IMAGES AND REPORT
214

FIG. 7

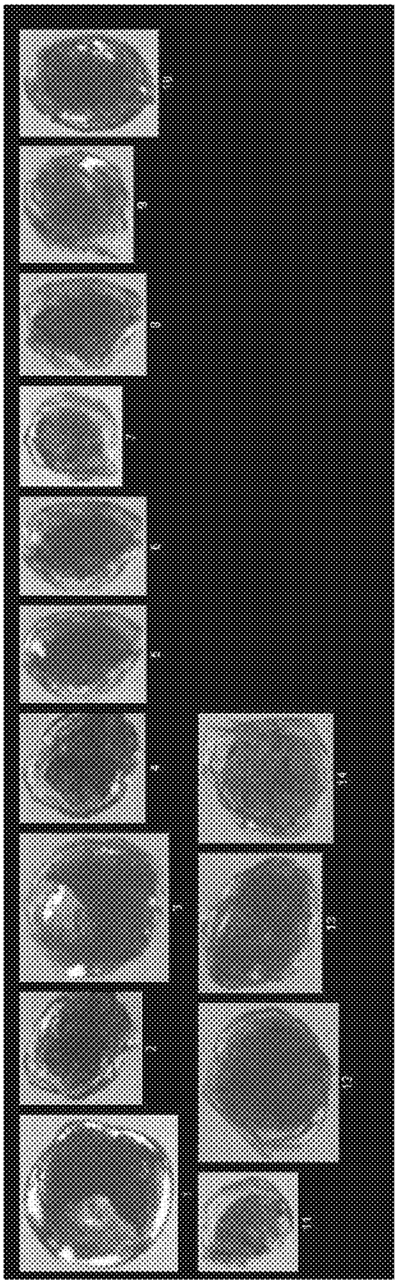

FIG. 8A

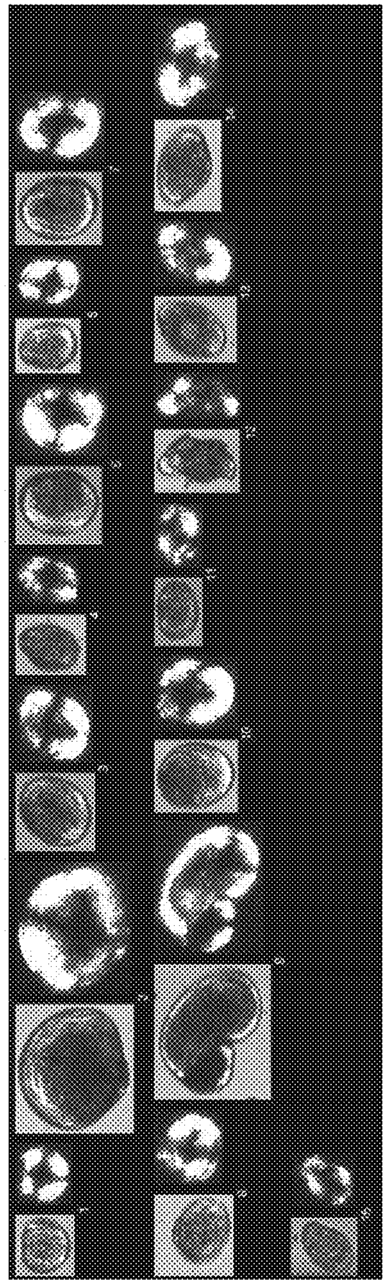

FIG. 8B

SYSTEM AND METHOD FOR MONITORING BIREFRINGENT PARTICLES IN A FLUID

CROSS REFERENCE TO RELATED APPLICATIONS

The present relates to, and claims the priority benefit of, U.S. Provisional Patent Application No. 61/086,010, filed Aug. 4, 2008, entitled SYSTEM AND METHOD FOR MONITORING ZEBRA MUSSELS IN A FLUID, of the same named inventors, and U.S. Nonprovisional patent application Ser. No. 12/535,536, filed Aug. 4, 2009, entitled SYSTEM AND METHOD FOR MONITORING BIREFRINGENT PARTICLES IN A FLUID, assigned to a common assignee. The entire content of those applications is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to an optical flow imaging and analysis configuration used in particle analysis instrumentation, and more particularly to a birefringent particle in-flow imaging system configured to enable the accurate identification of particles in a fluid.

2. Description of the Prior Art

The art has seen various optical/flow systems employed for transporting a fluid within an analytical instrument to an imaging and optical analysis area. A liquid sample is typically delivered into the bore of a flow chamber and this sample is interrogated in some way so as to generate analytical information concerning the nature or properties of the sample. For example, a laser beam may excite the sample that is present in the bore of the capillary, with the emitted fluorescence energy representing the signal information.

In the area of identifying birefringent particles, such as crystals, in a fluid, the closest known relevant technological developments involve manual microscope measurements, which is not flow augmented to enable the easy counting and detection of such particles. It would be advantageous to detect with accuracy the existence and density of particles in a flow stream for various reasons. For example, Zebra Mussels are an invasive fresh water mussel species that can foul power plant water intakes and can take over the ecosystem in fresh water lakes and ponds. A flow system such as that described in this document would lend itself to automation in a way that would facilitate the accurate detection of Zebra Mussels and other types of birefringent particles, such as those particles responsive to cross polarization.

The inefficiencies of manually counting particles with a microscope may result in inconclusive counts based on the less than optimum collection of water samples from a pond or lake sample. This microscope method is also tedious and time consuming. It also does not lend itself to easy automation.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an imaging system arranged to detect with reliable accuracy the existence of particles in a flowing fluid. It is also an object of the present invention to provide such an imaging system that may be incorporated into, or operate in a similar manner as that of, existing particle-in-fluid imaging systems.

These and other objects are achieved with the present invention, which is a system with a detection mechanism that includes polarization analyzers arranged with their polarization axes perpendicular to one another, resulting in the passage of light to a camera or cameras only when a particle with detectable birefringence is between the analyzers. Particles with detectable birefringence show up with a distinct "Maltese cross" pattern. The system further includes a video system arranged to image particles in the fluid passing through the flow chamber in response to the trigger signals. Images captured by the video system are of high resolution and may be used in comparison to known particle images of a library of images. Computer programming is created to operate a computing device of the system to match (or recognize non-matching) of captured images with known particle images of the library. Identification of the particles in the flowing fluid may then be made.

The system and related method of the present invention enhances the accuracy and sensitivity of birefringent particle monitoring including, but not limited to, minerals, pharmaceuticals, emulsions, crystals (including crystalline organic structures such as Zebra Mussels) and fibers monitoring, by utilizing imaging systems combined with birefringent particle analysis.

The advantages gained by the invention compared to the state of the art of currently available methods are: 1) more accurate measurements of individual organism counts from scatter signals and birefringence imaging; and 2) better ability to easily monitor for such particles versus conventional manual microscope techniques. In the two LED/two camera embodiment of the invention the infrared LED penetrates the shells of the veligers and allows imaging of internal features that would not be possible with strictly visible illumination. The red illumination provides sharper imaging of the external features than would be possible with infrared imaging. Therefore, when used together, the two LEDs result in veliger images with sharp external features and visible internal features. These and other advantages of the present invention will become more readily apparent upon review of the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** schematically illustrates a system for studying particles in a fluid according to a first embodiment of the invention.

FIG. **2** schematically illustrates a system for studying particles in a fluid according to a second embodiment of the invention.

FIG. **3** is an enlarged perspective view of the flow chamber of the systems of FIGS. **1** and **2**.

FIG. **4** is a detailed schematic illustration of the plurality of detectors and associated filters for capturing distinct birefringence images of particles within a flowing fluid in a first embodiment of the invention.

FIG. **5** is a detailed schematic illustration of the plurality of detectors and associated filters for capturing distinct birefringence images of particles within a flowing fluid in a second embodiment of the invention.

FIG. **6** is a flow diagram representing steps to be carried out using the computing device and associated programming of the first embodiment of the present invention.

FIG. **7** is a flow diagram representing steps to be carried out using the computing device and associated programming of the second embodiment of the present invention.

FIG. **8**A shows images of mussel veligers using the first embodiment of the invention, and FIG. **8**B shows images of veligers using the second embodiment of the invention, illustrating how more prominently the polarization "Maltese cross" shows up due to the infrared illumination. In FIG. **8**B there is one image from each of the two cameras in the system for each sample. FIG. **8**B also shows how the infrared improves the crispness of the internal features of the mussel veligers due to the more penetrating nature of the infrared light.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A system **10** of the present invention suitable for high quality automated counting and imaging of particles exhibiting birefringence characteristics and that exist in a fluid is shown in FIGS. **1** and **3**. The system **10** includes a flow chamber **15**, a pump **20**, a light source **30**, an imaging and optics system **35**, an image detection system **40** including control electronics **45**, a backlighting generator **50**, an image capturing system **60** and a computing device **65**. The combination of these components of the system **10** arranged and configured as described herein enable a user to detect birefringent particles in the fluid and, specifically, to enhance the accuracy and sensitivity of such detection.

As shown in FIG. **3**, the flow chamber **15** includes an inlet **16** for receiving the particle-containing fluid to be observed, and an outlet **17** through which the fluid passes out of the flow chamber **15** after imaging functions have been performed. The flow chamber **15** may be fabricated of a material suitable for image capturing, including, for example, but not limited to, transparent microscope glass or rectangular glass extrusions. The flow chamber **15** may be circular or rectangular in shape. The flow chamber **15** defines a channel **15***a* through which the fluid flows at a predetermined selectable rate. The channel **15***a* may be of rectangular configuration. The length and width of channel **15***a* are selected to roughly match the field of view of the imaging optics **35**. This keeps all of the particles flowing through the flow chamber in focus, removing the need for a focusing sheath flow, and thereby enabling accurate counting of cells while retaining imaging capability. The inlet **16** of the flow chamber **15** is connectable to a fluid source and the outlet **17** is connectable to a downstream means for transferring the fluid away from the flow chamber **15**.

With reference to FIGS. **1** and **4**, the light source **30** is used to generate scatter excitation light which is passed through the optics and imaging system **35** to the flow chamber **15**, resulting in light scatter by particles located in the fluid. The light source **30** may be a laser with a wavelength filter **33**. The laser **30** may be, but is not limited to being, a 470 nanometer (nm), 488 nm or 532 nm solid state model laser available from an array of manufacturers known to those of skill in the art. The filter **33** should at least have the characteristic of being able to transmit light at the wavelengths of light generated by the laser **30**. An example of a suitable form of the filter **33** is a 532/10× filter of the type that can be used with a 532 nm laser available from Chroma Technologies of Rockingham, Vt. US; those of skill in the art will recognize that other suitable filters may be employed for the filter **33**. Dichroic mirror **80** blocks laser reflections from the flow chamber **15** and allows wavelengths of light longer than that of the laser **30** to the imaging section of the system **10**. An example of a suitable filter which will work with a 532 nm laser is a 505DCLP longpass filter from Chroma Technologies.

With continuing reference to FIGS. **1** and **4**, the imaging and optics system **35** includes a microscope objective **75** to image the particle flow onto the image capturing system **60** and focus excitation light from the light source **30** onto the flow chamber **15**. The control electronics **45** may be configured to receive input signals and produce output information compatible with the specific needs of the user of the system **10**. An example of a suitable electronics system capable of performing the signal activation and output information associated with the control electronics **45** of the system **10** is the detection electronics described in U.S. Pat. No. 6,115,119, the entire content of which is incorporated herein by reference. Those of ordinary skill in the art will recognize that the specific electronics system described therein may be modified, such as through suitable programming for example, to trigger desired signal activation and/or to manipulate received signals for desired output information.

The light source **30** may be operated to transmit light periodically, sporadically, or regularly. For example, the light source may emit light signals and a scatter detector **51** may be employed on the back side of the flow chamber **15** to detect changes in light signals from the light source, such as when a particle passing through the flow chamber **15**. The scatter detector **51** may be any type of suitable device capable of detecting variations in received light and transmitting electrical signals indicative of the light variations. In one embodiment, the scatter detector **51** may be an array of photoreceptive sensors. The scatter detector **51** is coupled to the control electronics **45** to signal to the control electronics the light change indicative of the existence of a particle in the flow chamber **15**. The control electronics **45** is coupled to the computing device **65**. The computing device **65** is programmed to store the information received from the control electronics **45** and to make calculations and processing decisions based on the information received. The computing device **65** may be any sort of computing system suitable for receiving information, running software programs on its one or more processors, and producing output of information, including, but not limited to images and data, that may be observed on a user interface.

In one embodiment of the invention, the control electronics **45** is also coupled, directly or indirectly through the computing device **65** to the backlighting generator **50**. In particular, the control electronics **45** and the computing device **65** are arranged to generate a trigger signal to activate the backlighting generator **50** to emit a light flash upon detection of a particle or particles in the flow chamber **15**. That is, the trigger signal generated produces a signal to activate the operation of the backlighting generator **50** so that a light flash is generated. Specifically, in one embodiment the backlighting generator **50** may be a Light Emitting Diode (LED) flash or other suitable light generating means that produces a light of sufficient intensity to backlight the flow chamber **15** and image the passing particles. The LED flash may be a 670 nm LED flash, or a flash of another other suitable wavelength of high intensity, which is flashed on one side of the flow chamber **15** for 200 μsec (or less). At the same time, the image capturing system **60** positioned on the opposing side of the flow chamber **15** is activated to capture an instantaneous image of the particles in the fluid as "frozen" when the high intensity flash occurs. Polarization analyzers **57** and **58** are deployed in the image path to modify the display of the particles located in the flow chamber **15**.

In a second embodiment of the invention identified as system **11** and represented in FIGS. **2** and **5**, the control electronics **45** and the computing device **65** are arranged to activate backlighting from a combination of two LEDs, a first LED **50***a* and a second LED **50***b*. In this system **11**, the first LED **50***a* is a 10 mm 3 chip 15 degree 200 mw 850 nm (infrared, "IR") LED. The second LED **50***b* is a 10 mm red 660 nm LED mounted next to the first LED **50***a*. The second LED **50***b* is configured to reflect off a 700 nm long pass filter **52**, such as an Edmunds 47-260 filter.

In both embodiments of the invention, the polarization analyzers **57** and **58** are crossed, meaning that under normal conditions, light filtered by analyzer **57** is polarized perpendicular to the polarization axis of analyzer **58** so little or no light can pass through **57** and then through **58**. The polarization analyzers **57** and **58** only allow light to reach the image capturing system **60** if it passes through particles, that is, birefringent particles, and has its polarization rotated or changed from linear to elliptical polarization. This is a very specific property of certain particles but is not applicable with respect to all particles. For example, it is suitable for use in detecting Zebra Mussels due to the calcite composition of its shells. More generally, for certain materials, the application of incident waves of different polarization will produce different indexes of refraction. This birefringence characteristic can be easily captured and used to identify a particular material in the fluid through the present invention since the birefringent particles will appear to glow with light when the water is imaged. The polarization analyzers **57** and **58** may be GT10B linear polarization analyzers available from Thorlabs of Newton, N.J. Those of ordinary skill in the art will recognize that suitable polarization analyzers may be used that are not crossed while still producing the birefringence information of interest in the detection of the existence of the particular material or materials of interest in the fluid.

The image capturing system **60** is arranged to either retain the captured image, transfer it to the computing device **65**, or a combination of the two. In the first embodiment, the image capturing system **60** includes characteristics of a digital camera or an analog camera with a framegrabber or other means for retaining images. For example, but in no way limiting what this particular component of the system may be, the image capturing system **60** may be, but is not limited to being, a CCD firewire, a CCD USB-based camera, or other suitable device that can be used to capture images and that further preferably includes computing means or means that may be coupled to computing means for the purpose of retaining images and to manipulate those images as desired. The computing device **65** may be programmed to measure the size and shape of the particle captured by the image capturing system **60** and/or store the data for later analysis.

In the second embodiment, the image capturing system includes two cameras, **60***a* and **60***b*. The first camera **60***a* has a polarizing filter **58**, and the second camera **60***b* operates in relation to the polarizing filter **57** in front of the infrared flash LED. The first and second cameras **60***a* and **60***b* work in conjunction with a 90/10 beam splitter **54**. The beam splitter **54** directs 90% of the light to the first camera **60***a*. The system **11** is arranged so that the first camera **60***a* and the second camera **60***b* will be brought into focus at the same place by adjusting the focal points of the cameras. Each of the cameras **60***a* and **60***b* may be, but is not limited to being, a CCD firewire, a CCD USB-based camera, or other suitable device that can be used to capture images and that further preferably includes computing means or means that may be coupled to computing means for the purpose of retaining images and to manipulate those images as desired. In a preferred embodiment, both the first camera **60***a* and the second camera **60***b* are JAI CM-080 Gig-E B/W cameras. The computing device **65** may be programmed to measure the size and shape of the particle captured by the image capturing system including cameras **60***a* and **60***b* and/or store the data for later analysis.

The images captured by the image capturing system **60** or the combination of cameras **60***a* and **60***b* and stored with the computing device **65** may be analyzed and compared to known images of particles including, for example, Zebra Mussels. When a trigger is generated (i.e., a light scattering particle is detected), software scans the resulting image, separating the different particle sub-images in it. The area of each particle is measured by summing the number of pixels in each particle image below a selectable threshold and multiplying the result by the equivalent physical area of a pixel. This computed area of the particle is stored in a spreadsheet-compatible file along with other properties of the particle, e.g., its measured peak fluorescence, time of particle passage, and the location of the particle in the image. The sub-image of each particle is copied from the chamber image and saved with other sub-images in a collage file. Several of these collage files may be generated for each system experiment. A special system file is generated, containing the collage file location of each particle sub-image, particle size and time of particle passage.

The software is written to generate two data review modes: (1) image collage and (2) interactive scattergram. In the image collage mode, the user may review a series of selectable sub-images in a collage file. Reviewing these files allows the user to identify particle types, count particles, or study other features. In interactive scattergram mode, data is presented to the user as a dot-plot; e.g., a graph of particle size. If the user selects a region of the scattergram, images of particles having the characteristics plotted in that region are displayed on a display of the computing device **65**, allowing the user to study particle populations and to examine images of particles with specific sizes, such as cells of a specific type. Because a spreadsheet compatible file is generated for each review, the user may also review the data with a spreadsheet program. This information allows the user to readily generate cell counts and scatter and size distribution histograms for each sample. This file also contains the location of each particle in the original image which is used to remove redundant data from particles that have become attached to the flow chamber **15**.

As represented in FIG. **6**, a method **200** of the present invention embodied in one or more computer programs, includes steps associated with storing and analyzing images captured with the system **10** of the present invention. In the first step, step **202**, the light source **30** and imaging optics **35** generate scatter excitation light, which is directed to the flow chamber **15** within which a fluid to be monitored passes, step **204**. The detection system **40** including the control electronics **45** is used to detect separately, images associated with the light waveforms scattered from particles in the flow chamber **15**. The detected images are transferred to the computing device **65** for storage and analysis, step **206**. The images captured are characterized based on particle shape and size, in addition to other information of interest, step **208**. Features representative of the birefringent particles in the fluid may be detected and that information may be reported in a visual manner, step **210**. For example, the information may be presented in graphic representations, spreadsheet lists, or combinations thereof. Optionally, the acquired image information may be used to count the number of particles in the fluid sample observed and reported, step **212**, and/or the captured images may be compared to known images of particles of interest and reported, step **214**.

As represented in FIG. **7**, a second method **201** of the present invention embodied in one or more computer programs, includes steps associated with storing and analyzing images captured with the system **11** of the present invention. In this embodiment, step **202** involves the generation of flash excitation light from two LEDs, LED **50***a* and LED **50***b*. In addition, step **206** involves the acquisition of the indicated image information from the first camera **60***a* and the second camera **60***b*. All other steps of method **201** correspond to the steps of the method **200**.

It is to be understood that the computing device **65** used to gather the captured image information and to perform calculations and observe features of the captured image information may be associated with local or remote computing means, such as one or more central computers, in a local area network, a metropolitan area network, a wide area network, or through intranet and internet connections. The computing device **65** may include one or more discrete computer processor devices. The computing device may include computer devices operated by a centralized administrative entity or by a plurality of users located at one or more locations.

The computing device **65** may be programmed to include one or more of the functions of the systems **10** and **11**. The computing device **65** may include one or more databases including information related to the use of the systems **10** and **11**. For example, such a database may include known images of example particles of interest. The database may be populated and updated with information provided by the user and others.

The steps of methods **200** and **201** described herein and additional steps not specifically described with respect to FIGS. **6** and **7** but related to the use of the systems **10** and **11** may be carried out as electronic functions performed through the computing device **65** based on computer programming steps. The functions configured to perform the steps described herein may be implemented in hardware and/or software. For example, particular software, firmware, or microcode functions executing on the computing device **65** can provide the trigger, image capturing and image analysis functions. Alternatively, or in addition, hardware modules, such as programmable arrays, can be used in the devices to provide some or all of those functions, provided they are programmed to perform the steps described.

The steps of the methods **200** and **201** of the present invention, individually or in combination, may be implemented as a computer program product tangibly as computer-readable signals on a computer-readable medium, for example, a non-volatile recording medium, an integrated circuit memory element, or a combination thereof. Such computer program product may include computer-readable signals tangibly embodied on the computer-readable medium, where such signals define instructions, for example, as part of one or more programs that, as a result of being executed by a computer, instruct the computer to perform one or more processes or acts described herein, and/or various examples, variations and combinations thereof. Such instructions may be written in any of a plurality of programming languages known to those of skill in the art including, for example, C++, but not limited thereto. The computer-readable medium on which such instructions are stored may reside on one or more of the components of systems **10**, **11** described above and may be distributed across one or more such components. Further, the steps of the method represented in FIG. **4**, may be performed in alternative orders, in parallel and serially.

The systems **10** and **11** of the present invention allows much greater sensitivity to birefringent particles due to individual particle measurements and verification of each particle with imaging. A specific example use of this invention involves the monitoring of Zebra Mussels in ponds and lakes. More generally, the systems **10** and **11** may be used to detect and analyze minerals, pharmaceuticals, emulsions, crystals and fibers, as well as any other type of structure with characteristics enabling birefringence analysis. The advantages of system **11** of the present invention are illustrated in FIGS. **8**A and **8**B. FIG. **8**B illustrates how more prominently the polarization "Maltese cross" shows up using the system **11** in comparison to the images established using the system **10** (represented by the images of FIG. **8**A), due to the infrared illumination, and also shows how the infrared improves the crispness of the internal features of the mussel veligers due to the more penetrating nature of the infrared light. As previously described, the invention is carried out by combining polarization analyzers with an imaging system and configuring the computing device **65**, through software to image the particle birefringence and then using known imaging capabilities to count and/or identify the particles, if desired.

One or more example embodiments to help illustrate the invention have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the invention.

What is claimed is:

1. A system for imaging birefringent particles in a flowing fluid, the system comprising:

a. a flow chamber including a channel arranged to transport the flowing fluid therethrough at a selectable rate;

b. a light source arranged to generate scatter excitation light to illuminate birefringent particles in the flowing fluid in the flow chamber;

c. a backlighting generator arranged to produce a light of sufficient intensity to backlight the flow chamber, wherein the backlighting generator includes two light emitting diodes;

d. a microscope objective arranged to focus light from the light source onto the flow chamber;

e. a scatter detector to detect changes in the light from the light source indicative of the existence of one or more particles in the flow chamber;

f. control electronics configured to receive signals from the scatter detector, wherein the control electronics are coupled to the backlighting generator and configured to activate the operation of the backlighting generator;

g. an image capturing system including one or more cameras to capture images of the birefringent particles in the flowing fluid, a first polarization analyzer and a second polarization analyzer, wherein the first polarization analyzer and the second polarization analyzer are arranged in a cross polarization configuration to permit the passage of light to the one or more cameras only when the birefringent particles with detectable birefringence pass between the first polarization analyzer and the second polarization analyzer; and

h. a computing device to receive signals from the control electronics and the image capturing system and to output information about the birefringent particles detected in the flowing fluid.

2. The system of claim **1** wherein the first polarization analyzer and the second polarization analyzer of the image capturing system are arranged with their axes perpendicular to one another.

3. The system of claim **1** wherein the one or more cameras include a digital or analog camera and a framegrabber.

4. The system of claim **1** wherein the light source is a laser with an excitation filter.

5. The system of claim **1** wherein the computing device includes a database to store data and images associated with detected particles and software to generate with the computing device particle data as image collages and interactive scattergrams.

6. The system of claim **1** wherein the image capturing system includes two cameras.

7. A method for imaging birefringent particles in a flowing fluid, the system comprising:

a. transporting the flowing fluid through a channel of a flow chamber at a selectable rate;

b. generating scatter excitation light to illuminate the flowing fluid in the flow chamber;

c. detecting scattered light signals indicative of the existence of one or more birefringent particles in the flow chamber;

d. backlighting the flow chamber upon detection of scattered light signals using two light emitting diodes;

e. cross polarizing light from the backlighting of the flow chamber with a first polarization analyzer and a second polarization analyzer to permit only light passing through birefringent particles to pass to one or more cameras to capture images; and

f. outputting information about the birefringent particles detected in the flowing fluid based on captured images thereof.

8. The method of claim **7** wherein the step of cross polarizing light includes placing the first polarization analyzer and the second polarization analyzer with their polarization axes perpendicular to one another in relation to the flow chamber so that light passes to the one or more cameras only when the birefringent particles pass between the first polarization analyzer and the second polarization analyzer.

9. The method of claim **7** wherein the one or more cameras include a digital or analog camera and a framegrabber.

10. The method of claim **7** wherein the step of generating scatter excitation light is achieved with a laser and an excitation filter.

11. The method of claim **7** wherein two cameras are used to capture images.

12. The method of claim **7** further comprising the steps of storing data and images associated with detected particles and generating particle data as image collages and interactive scattergrams.

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